

## **Testing Nonlinear Inflation Convergence for the Central African Economic and Monetary Community**

**Emmanuel Anoruo**

Coppin State University, Baltimore, Maryland, USA.  
Email: eanoruo@coppin.edu

**Vasudeva N.R. Murthy**

Creighton University, Omaha, Nebraska, USA.  
Email: vmurthy@creighton.edu

**ABSTRACT:** This paper uses nonlinear unit root testing procedures to examine the issue of inflation convergence for the Central African Economic and Monetary Community (CEMAC) member states including Cameroon, Central African Republic, Chad, Equatorial Guinea, Gabon and the Republic of Congo. The results from nonlinear STAR unit root tests suggest that inflation differentials for the sample countries are nonlinear and mean reverting processes. These results provide evidence of inflation convergence among countries within CEMAC. The finding of inflation convergence indicates the feasibility of a common monetary policy and/or inflation targeting regime within CEMAC.

**Keywords:** inflation convergence; STAR; nonlinear unit root tests; inflation differential; CEMAC

**JEL Classifications:** C22; E31; F15; F36

### **1. Introduction**

The issue of inflation convergence has become an important topic in both domestic and international macroeconomics. Inflation convergence in a group of similar countries indicates the integration of goods markets. In integrated markets, inflation rates generally exhibit convergence in the long run. Inflation convergence also has many policy implications for the effectiveness of the countries' Central Banks' monetary policies. Furthermore, for reliable econometric modeling for both structural analysis and forecasting, the order of the time series needs to be tested. While there is a plethora of econometric studies investing the convergence of inflation rates for many advanced countries and Organization of Economic Co-operation and Development (OECD) countries exists, hardly there are any serious econometric attempts to test this phenomenon for African countries. The need for investigating the inflation convergence in African countries is imminent as many of these countries are implementing economic liberalization policies, experiencing globalization, getting integrated, and becoming a part of the recent technological revolution in communications. Furthermore, often, some of these countries aspire for the formation of common currency and monetary areas.

Even for the advanced and OECD countries, most of the existing studies employ the widely used Dickey-Fuller (DF) and the augmented Dickey-Fuller (ADF) type linear unit root tests. Recently, it has been empirically demonstrated that the statistical power of the linear unit root type tests are very low if the true data generating process (DGP) is indeed nonlinear in nature. When we study inflation in a particular economy or convergence of inflation phenomenon across countries, it is quite apparent that inflation rates may exhibit nonlinearities in the presence of transaction costs, arbitrage and especially, inflation targeting monetary policies. Under inflation targeting, the DGP becomes a nonlinear process because the responsiveness of the Central Bank may change depending on whether the prevailing inflation rate is above or below a well-defined target, thus creating a "band of inaction" (See, Kapetanios et al. 2003: Christopoulos and Leon-Ledesma, 2007). In the literature, recently there have been some empirical attempts to employ nonlinear unit root tests, especially in the case of developed countries. For instance, Gregoriou and Kantonikas (2006) using nonlinear unit root testing procedure examined the time series properties of inflation in seven countries (i.e. Australia, Canada, Chile, Israel, New Zealand, Sweden and UK) that have adopted inflation targeting. They found that inflation deviations from the target for the seven sample countries are characterized by a nonlinear mean-reverting process. Based on this finding,

they concluded that the implementation of inflation targeting strategy by these countries has been a success. Kočenda and Papell (1997) examined the issue of inflation convergence for the European Union using a panel data approach. They find evidence of inflation convergence within the European Union. Holmes (2002) using panel data unit root and cointegration procedures investigated the extent of long run inflation convergence among the European Union countries. He finds evidence in support of inflation convergence for the sample countries during the time period 1983 through 1990. Gregoriou and Kontonikas (2009) model the behavior of inflations from the target for a sample of five OECD countries including Australia, Canada, New Zealand, Sweden and the United Kingdom. These five countries adopted inflation targeting regimes over the 1990s. They find that inflation deviations from the target are nonlinear. They therefore concluded that inflation differentials should be modeled as nonlinear processes. Spuru (2008) using time series and panel unit root testing procedures, examined the issue of nonlinear inflation convergence for Central and East European (CEE) economies. Spuru finds that inflation rates for the sample countries are nonlinear and have converged. Spuru, further points out that participation in the Exchange Rate Mechanism (ERM) tends to favor inflation convergence. However, the introduction of a single currency and a common monetary policy account for a certain degree of divergence within the CEE.

Weber and Beck (2005) investigate both the extent and dynamics of inflation differentials in major EMU countries; pre- and post- the introduction of the euro. They find evidence that inflation differentials for the sample countries are mean reverting indicating the existence of  $\beta$ -convergence. Buseti, et al. (2006) examined the convergence properties of inflation differentials for countries of the European Monetary Union (EMU) for the time period running from 1980 through 2004. They divided the sample period into two; 1980 – 1997 and 1998 – 2004. They find evidence supportive of inflation differentials for the period 1980 through 1997 but not for the second period running from 1998 to 2004. Lane (2006) examined the time series properties of inflation differentials for EMU member countries. Lane found that inflation differentials among EMU member states are persistent. Kisswani and Nusair (2011) using the standard augmented Dickey-Fuller (ADF) unit root test examined the time series properties of inflation differentials for Indonesia, Malaysia, the Philippines, Singapore and Thailand relative to the U.S. and Japan. They found that the inflation differential series are stationary, indicating the existence of inflation convergence among the sample countries.

The preceding studies focused attention on the issue of inflation convergence in the context of EMU. Thus, it is evident that little or no attention has been devoted on this issue relative to monetary unions in Africa, including CEMAC. The success of the EMU cannot be generalized to Africa. Kimenyi and Kuhlmann (2012) point out that the regional integrations in Africa face a number of challenges such as political instability, social and cultural barriers, weak infrastructure and multiple memberships in regional organizations. In addition, most of the earlier studies used linear unit root tests, which have been shown in the literature to have low statistical power in the presence of nonlinearity. This paper makes two contributions to the literature. First, the study extends the discussion on inflation convergence to the Central African Economic and Monetary Community (CEMAC) countries. Second, the study applies the Kapetanios, Shin and Snell (hereafter KSS) and Kruse (2011) procedures that take into account the ability to account for both possible nonlinear trends and asymmetric adjustment in the mean reversion process.

The remainder of the paper is organized as follows. Section 2 discusses the econometric techniques of the study. Section 3 presents the data and the descriptive statistics. Section 4 furnishes the empirical results. Section 5 offers the summary and policy implications of the study.

## **2. Econometric Techniques**

The empirical analysis of the study begins with the application of the linear unit root procedures advanced by Ng and Perron (2001). The Ng and Perron (2001) unit root procedures combine the Modified Information Criterion and the Generalised Least Squares methods to attain better power and size. In particular, they proposed the following unit root procedures; the  $MZ\alpha^{GLS}$ ,  $MZt^{GLS}$ ,  $MSB^{GLS}$  and the  $MP_T^{GLS}$ . The  $MZ\alpha^{GLS}$  and  $MZt^{GLS}$  are the modified versions of the Phillips' (1987) conventional unit root tests. The  $MSB^{GLS}$  refers to the modified version of Bhargava's (1986) standard  $R_1$  test while the  $MP_T^{GLS}$  is the modified version of the Point Optimal procedure proposed by Elliot et al. (1996).

To ascertain whether the inflation differentials exhibit nonlinear behavior, this paper also implements the BDS test proposed by Brock et al. (1987, 1996). The study provides a brief description of the BDS procedure as this test has become standard and has been extensively used in the extant literature. The BDS test is applied to the residuals of the series of interest (in our case, inflation differentials). The test statistic is assumed to be asymptotically standard normally distributed with zero mean and a unit variance [i.e.  $N(0,1)$ ]. Under the BDS test, the null hypothesis is that the variable of interest is independently and identically distributed. The rejection of the null hypothesis indicates the presence of nonlinearity in the data generating process. The complete underpinnings of the BDS test can be found in Brock et al. (1987, 1996).

### 2.1 KSS (2003) Unit Root Test

Kapetanios, Shin and Snell (2003) (hereafter KSS) have shown that a DGP's nonlinear unit root behavior can be captured through a model that allows the autoregressive parameter to vary smoothly in a two regime model for which the change in regime is smooth rather than abrupt. Moreover, in such a model, the nonlinear behavior of the data generating process shows symmetric adjustments for deviations above and below the equilibrium level. They call their model, the exponential star model [ESTAR]. In this paper, we follow their suggestion in the literature to test the mean reversion property of the inflation differential series for CEMAC countries. A brief introduction of KSS is in order. For a detailed mathematical discussion of the model, see Kapetanios et al., 2003]. Kapetanios et al. (2003) specify the following ESTAR model for the DGP,  $x_t$ :

$$\Delta x_t = \varphi x_{t-1} + \gamma x_{t-1} [(1 - \exp(-\theta x_{t-d}^2))] + \varepsilon_t \quad (1)$$

Where,  $\theta$  is a parameter that determines the degree of mean reversion. The stochastic term  $\varepsilon_t$  is assumed

to be normally distributed, with a zero mean and a constant variance. In model (1), the maintained hypotheses are that  $H_0$ : unit root ( $\theta=0$ ) and that  $H_A$ : Nonlinear, but globally stationary ( $\theta > 0$ ).

As testing (1) is not mathematically feasible given that  $\lambda$  is not identified under the null hypothesis, KSS suggest that we use a first-order Taylor approximation to estimate the ESTAR model (1) under the null by re-estimating the following regression model controlling for serial correlation by adding the lagged terms:

$$\Delta x_t = \delta x_{t-1}^3 + \sum_{i=1}^j \rho_i \Delta x_{t-i} + error_t \quad (2)$$

In model (2), the null hypothesis is that  $\delta = 0$  and the alternate hypothesis is that  $\delta < 0$ . In order to estimate the KSS nonlinear model (2), it is suggested that we employ the technique of the Ordinary Least Squares (OLS). For conducting the unit root test, the test statistic  $t_{NL}$ , is obtained by dividing the estimated  $\delta$  in the model (2) by its standard error and reported as  $t_{NL} = \hat{\delta} / S.e.(\hat{\delta})$ . KSS provide the critical values at the 1%, 5% and 10% significance to be used in conducting the test.

### 2.2 Kruse (2011) Nonlinear Unit Root Test

Kapetanios et al. (2003) assume that in the original specified model along the lines of (1), the location parameter,  $c$ , to be zero. But, recently, Kruse (2011) has shown that in real world examples, the possibility of non-zero location parameter is imminent. Therefore, he extends the Kapetanios et al. (2003) unit root test to allow for a nonzero location parameter. This test is called, in the time-series econometrics literature, the Kruse tau test. [See, for a detailed mathematical discussions and statistical derivations, Kruse (2011)]. Furthermore, Kruse (2011) provides the critical values for conducting this test, besides statistically demonstrating the superiority of the test. He shows that the Kruse tau test performs extremely well in terms of statistical power and size properties.

## 3. Data and Descriptive Statistics

The data consist of quarterly observations on Consumer Price Index (CPI) for Cameroon, Central African Republic, Chad, Equatorial Guinea, Gabon and the Republic of Congo. The data were retrieved from the *International Financial Statistics* (CD October 2012) published by the International Monetary Fund (IMF). Inflation rates for the sample countries were calculated using the following expression:

$$\pi_t = \left( \frac{P_t}{P_{t-1}} \right) * 100 \quad (3)$$

Where  $\pi_t$  is the rate of inflation and P is the consumer price index. The study period runs from the second quarter of 1990 through the first quarter of 2012. Table 1 furnishes the descriptive statistics for the inflation rate series. The mean values for inflation rates ranged from a high of 1.66 percent for Chad to a low of 0.58 percent for Gabon. The minimum and maximum statistics reveal inflation rates fluctuated within the study period. For example, the inflation rate for Cameroon varied from a minimum of -3.25 percent to a maximum of 18.66 percent. The statistics presented in Table 1 reveal that Chad (5.32 percent) posted the highest standard deviation while Cameroon (2.57 percent) recorded the least. The results show that inflation rates for the sample countries are positively skewed with the exception of Equatorial Guinea. The Jarque-Bera and Kurtosis statistics indicate that inflation rates are statistically significant. These statistics suggest that inflation rates for the sample countries are characterized by much higher distributions than the normal distribution.

**Table 1. Summary Statistics of Inflation Rates**

	Cameroon	CAR	Chad	Eq. Guinea	Gabon	Rep. of Congo
Mean	0.95	0.92	1.02	1.66	0.58	1.28
Maximum	18.66	15.35	24.58	13.34	18.87	25.56
Minimum	-3.25	-3.46	-10.52	-10.74	-10.21	-7.53
Std. Dev.	2.57	2.77	5.32	3.58	3.20	3.93
Skewness	4.39	2.20	1.09	-0.21	2.36	3.14
Kurtosis	28.92	11.15	6.86	7.74	17.84	19.31
Jarque-Bera	2747.39***	314.28***	72.00***	83.16***	889.32***	1119.95***
Probability	0.00	0.00	0.00	0.00	0.00	0.00

\*\*\* indicates rejection of the normality assumption at the 1% level of significance

In order to test inflation convergence, we define inflation differential as:

$$y_t = \pi_{it} - \pi_{xt} \quad (4)$$

In equation (4),  $\pi_{it}$  is the observed rate of inflation in the  $i^{\text{th}}$  country during a given period and  $\pi_{xt}$  is the average rate of inflation for CEMAC during the same time period. The order of integration of the variable  $y_t$  is used to determine the presence or lack of convergence of inflation differentials. If the observed  $y_t$  variable for a given country is found to have one order of integration [i. e.  $I \sim (0)$ ], then the variable or the series is stationary and hence, there is inflation rate convergence.

#### 4. Empirical Results

The empirical results of the study are discussed in this section. Table 2 displays the results from the linear Ng and Perrion (2001) unit root tests including the  $MZ_a^{GLS}$ ,  $MZ_t^{GLS}$ ,  $MSB^{GLS}$  and  $MP_T^{GLS}$ . These tests produced mixed results. For example, in the case of Cameroon, the results from the  $MZ_a^{GLS}$  (-25.44) and  $MZ_t^{GLS}$  (-3.56) tests suggest that the null hypothesis that the inflation differential series are unit root processes should be rejected at the 1 percent level of significance. However, the test results from the  $MSB^{GLS}$  (0.14) and  $MP_T^{GLS}$  (0.97) are all less than the critical values at the conventional levels indicating that the null hypothesis that the inflation differentials are unit root processes should not be rejected. Similar results are indicated for the other sample counties. The results from the  $MZ_a^{GLS}$ ,  $MZ_t^{GLS}$ ,  $MSB^{GLS}$ , and  $MP_T^{GLS}$  linear unit root procedures are inconsistent. As it has been noted in the literature, linear unit root tests tend to suffer from low power in the presence of nonlinearity in the data generating process.

Given the inconsistent results provided by the linear unit root testing procedures, the study next applies a battery of nonlinear unit root tests. In particular, the study implements the KSS nonlinear unit root tests. Prior to implementing the nonlinear STAR unit root tests, the study utilized the BDS procedure to test the null hypothesis of linearity against the alternative of a nonlinear model. The results from the BDS tests are presented in Table 3. Based on the results from the BDS procedure, the null hypothesis of linearity is rejected in favor of the alternative of nonlinearity in all of the cases. For example, in the case of Cameroon, the test statistic is 3.904 with a p-value of 0.000, indicating that the null hypothesis should be rejected at the 1 percent level of significance. Similar results are

indicated for the other sample countries with the exception of the Republic of the Congo, where the null hypothesis is rejected at the 5 percent level of significance.

**Table 2. Ng and Perron (2001) Unit Root Test Results**

Series	Lag(s)	$MZ_a^{GLS}$	$MZ_t^{GLS}$	$MSB^{GLS}$	$MP_T^{GLS}$
Cameroon	1	-25.44***	-3.56***	0.14	0.97
Central African Republic	0	-42.30***	-4.52***	0.11	0.79
Chad	1	-108.16***	-7.35***	0.07	0.23
Equatorial Guinea	8	0.17	0.27	1.61***	139.33***
Gabon	0	-42.97***	-4.63***	0.11	0.57
Republic of the Congo	3	-4.28	-1.45	0.34***	5.74***
Critical Values					
1%		-13.80	-2.58	0.17	1.78
5%		-8.10	-1.98	0.23	3.17
10%		-5.70	-1.62	0.28	4.45

\*\*\* and \*\* indicate rejection of nonlinearity hypothesis at the 1%, and 10% levels, respectively. The optimal lags were determined by the modified Akaike Information Criterion.

**Table 3. BDS Linearity Test Results**

Series	<i>Stat</i>	<i>M</i>	<i>P-Value</i>	<i>Decision</i>
Cameroon	3.904***	5	0.000	Reject $H_0$
Central African Republic	2.625***	5	0.009	Reject $H_0$
Chad	-5.555***	9	0.000	Reject $H_0$
Equatorial Guinea	8.307***	5	0.000	Reject $H_0$
Gabon	3.046***	5	0.002	Reject $H_0$
Republic of the Congo	1.948**	5	0.050	Reject $H_0$

\*\*\* and \*\* indicate rejection of linearity hypothesis at the 1%, and 10% levels, respectively.

Having established that the inflation differentials for CEMAC member countries are nonlinear, the study next applies the KSS nonlinear unit root tests. The nonlinear KSS unit root tests were conducted using the raw, demeaned and detrended inflation differential data for CEMAC member states. Table 4 presents the results from the nonlinear KSS unit root test results. The results suggest that the null hypothesis of nonlinear unit root in the inflation differentials for the sample countries should be rejected. In each case, the test statistic is greater than the critical value at least at the 5 percent level of significance. For instance, in the case of Cameroon, the test statistics -3.66, 3.78, and -3.75, respectively for raw, demeaned and detrended inflation differential data are statistically significant at the 1 percent significance level. The results from the KSS procedure indicate that the null hypothesis of nonlinear unit root should be rejected for the inflation differentials for the sample CEMAC member states.

**Table 4. KSS Nonlinear Unit Root Test Results**

Series	Raw	Demeaned	Detrended
Cameroon	-3.66***	-3.78***	-3.75***
Central African Republic	-4.14***	-4.20***	-4.33***
Chad	-4.99***	-4.99***	-5.15***
Equatorial Guinea	-6.28***	-5.82***	-5.83***
Gabon	-2.66**	-2.99**	-3.40**
Republic of the Congo	-7.13***	-7.11***	-7.11***
Critical Values			
1%	-2.82	-3.48	-3.93
5%	-2.22	-2.93	-3.40
10%	-1.92.85	-2.66	-3.13

\*\*\* and \*\* indicate rejection of the null hypothesis at the 1%, and 5% levels, respectively

To check the robustness of the results obtained from the KSS nonlinear unit root tests, the study applies the Kruse (2011) nonlinear unit root testing procedure. Again, the Kruse (2011) nonlinear unit root tests are conducted using the raw, demeaned and detrended inflation differential data for CEMAC member states. Table 5 displays the nonlinear unit test results from the Kruse (2011) procedure. The results indicate that the null hypothesis of nonlinear unit root in the inflation differentials for the sample countries should be rejected at least at the 5 percent level in all of the cases.

**Table 5. Kruse Nonlinear Unit Root Test Results**

Series	Raw	Demeaned	Detrended
Cameroon	14.78 <sup>***</sup>	15.43 <sup>***</sup>	15.41 <sup>***</sup>
Central African Republic	18.95 <sup>***</sup>	19.54 <sup>***</sup>	20.50 <sup>***</sup>
Chad	24.59 <sup>***</sup>	24.60 <sup>***</sup>	26.18 <sup>***</sup>
Equatorial Guinea	44.31 <sup>***</sup>	40.34 <sup>***</sup>	40.41 <sup>***</sup>
Gabon	7.86 <sup>*</sup>	10.73 <sup>**</sup>	13.20 <sup>**</sup>
Republic of the Congo	50.19 <sup>***</sup>	50.04 <sup>***</sup>	50.07 <sup>***</sup>
Critical Values			
1%	13.15	13.75	17.10
5%	9.53	10.17	12.82
10%	7.85	8.60	11.10

<sup>\*\*\*</sup>, <sup>\*\*</sup> and <sup>\*</sup> indicate rejection of the null hypothesis at the 1%, and 10% levels, respectively

Taken together, the results from the various nonlinear unit root tests reveal that inflation differentials for CEMAC member states are nonlinear stationary processes. These results provide evidence in support of inflation convergence among CEMAC members. This finding is consistent with Holmes (2002) and Kocenda and Papell (1997) who found evidence supportive of inflation convergence within the European Union.

## 5. Summary and Policy Implications

This paper has examined the existence of inflation convergence among CEMAC member countries — namely, the Central African Economic and Monetary Community (CEMAC) member states including Cameroon, Central African Republic, Chad, Equatorial Guinea, Gabon and the Republic of Congo. In particular, the study applied a number the KSS and Kruse (2011) nonlinear unit root tests. The results from these unit root testing procedures indicate that the inflation differentials are nonlinear and stationary processes. The policy implications of the findings of convergences are twofold. First, the finding of convergence implies that shocks to inflation differentials are not persistent indicating that the goods markets for the CEMAC member states are integrated. Second, the existence of inflation convergence among CEMAC member states weakens the effectiveness of their domestic monetary policy tools.

For further research, it would be informative to extend the discussion on inflation convergence to other regional integrations in Africa using nonlinear unit root procedures such as those applied by the present study. It would also be interesting to trace the source of nonlinearity in the inflation differential series for CEMAC member states.

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